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OCEANOGRAPHIC SURVEY OF THE GULF OF MEXICO

Office of Naval Research
Contract N7 onr-48702
Bureau of Ships
NE 120219-5

Navy Department
Project NR 083 036
Technical Report No. 10
November 1953

Submarine Topography of the Continental Slope of the Bay of Campeche

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Research Conducted through the

Texas A.&M. Research Foundation

COLLEGE STATION, TEXAS

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College Station, Texas

Research conducted through the
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Project 24

SUBMARINE TOPOGRAPHY OF THE CONTINENTAL SLOPE OF THE BAY OF CAMPECHE

Project 24 is an Oceanographic Survey of the Gulf of Mexico sponsored by the Office of Naval Research (Project NR 083 036, Contract N7onr-487 T.O. II) and the Bureau of Ships (NE 120219-5). The work reported herein is of a preliminary nature and the results are not necessarily in final form.

Report prepared October 26, 1953
by
Joe S. Creager

Dale F. Leipper
Project Supervisor

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ABSTRACT

A chart of the continental slope and gulfward bottom of the Bay of Campeche, contoured at an interval of 100 fathoms, reveals that this area is divided into five geomorphic provinces with strongly contrasting topography. Four of these geomorphic provinces lie on the continental slope. From the northwest corner of the Bay proceeding counter-clockwise the author has named them Tampico Province, Volcanic Province, Grijalva Delta Province, and NE Orogenic Province. The fifth province which comprises the portion of the Bay gulfward of the continental slope has been named Basin of the Bay of Campeche.

Very little information is available for the area covered by the Tampico Province. The data are more plentiful in the Basin of the Bay of Campeche and indicate an almost featureless bottom here that slopes gently gulfward. Therefore, these two provinces are passed over rapidly.

The remaining three provinces, Volcanic Province, Grijalva Delta Province, and NE Orogenic Province, present very interesting and diversified topographies. The Volcanic Province exhibits a series of benches separated by escarpments that are interpreted as a faulted lava plain. Slumping due to an overloading by volcanics has been postulated as the factor responsible for obscuring the benches in those areas where they are absent or only partially identified. The Grijalva Delta Province is an area with a highly undulating bottom made up of large closed basins, ridges and knobs. This type of topography and the fact that it is found only below depths of 600 fathoms is interpreted as the result of slumping and consequent folding and faulting related to the slumping. The continental slope of the NE Orogenic Province between the continental shelf edge and the 1700 fathom isobath is characterized by a smooth even slope of about 10°45'. This slope is interpreted as a fault scarp that bounds the probable Yucatan horst.

The change in slope between the continental shelf and the continental slope is found to lie between 40 and 100 fathoms in the Volcanic, Grijalva Delta and NE Orogenic Provinces.

A definite steepening (escarpment) is found along the seaward margin of the continental slope in the NE Orogenic and Grijalva Delta Provinces. This escarpment is seen to lie at a shallower depth in the Grijalva Delta Province than in the NE Orogenic Province. This escarpment is interpreted as indicating recent diastrophism along the outer margin of the continental slope with the gulfward portion subsiding relative to the landward portion. The fact that the escarpment is vague or absent in the profiles across the Volcanic Province, suggests that the greatest amount of movement accompanying this relative subsidence occurs on the east side of the Bay.

SUBMARINE TOPOGRAPHY
OF THE CONTINENTAL SLOPE
OF THE BAY OF CAMPECHE

I. INTRODUCTION

A. Nature of the Study

The objectives of this study are threefold: (1) to assemble the available depth soundings for the Bay of Campeche, a southern sector of the Gulf of Mexico; (2) to chart the bathymetry; and (3) to interpret the results geomorphologically. Carrying out these three objectives constitutes a reconnaissance survey of the bottom configuration of the Bay of Campeche.

These objectives are carried out by a compilation by the author of all the available depth soundings on the accompanying chart, including several hundred which cannot be released at present, by a contouring of these soundings also on the accompanying chart, and by the author's interpretation of the resulting topography as will be seen in Section III. C. All data have been accumulated from research other than that by the author. The author's contribution lies in the compilation, analyzing and interpretation of these data.

The published record does not show that the deep water area of the Bay of Campeche has previously come under direct geological investigation. As it covers a large sector of the Gulf, its study is involved in a number of larger, particularly interesting problems that are currently attracting the attention of geologists. Paul Weaver (1950) says about the Gulf: "The two theories — one that the present coast line is a hinge line, and the other that the zone of active movement is on the continental slope -- will be tested by geophysical surveys and to some extent by drilling. Both kinds of proof are very costly, and if the geologist can obtain enough evidence from hydrographic surveys and bottom samples so that he can recommend local areas for test of the two theories, he will speed the evaluation and operating program (of petroleum development) of the continental shelf with maximum efficiency." Many geologists have given us their ideas on the origin and history of the Gulf of Mexico as a whole, but until the entire area has been adequately mapped so as to provide a sound starting point as a basis for a theory no one of these hypotheses can stand out above the others. It was with the thought in mind of contributing to this mapping that this research was undertaken.

At first it may appear as if this study is being undertaken with insufficient data. However, in comparison with the vast areas of sea floor for which there is no knowledge this contribution may be con-

BASE MAP
TEXAS A. & M. RESEARCH FOUNDATION
DIVISION OF OCEANOGRAPHY

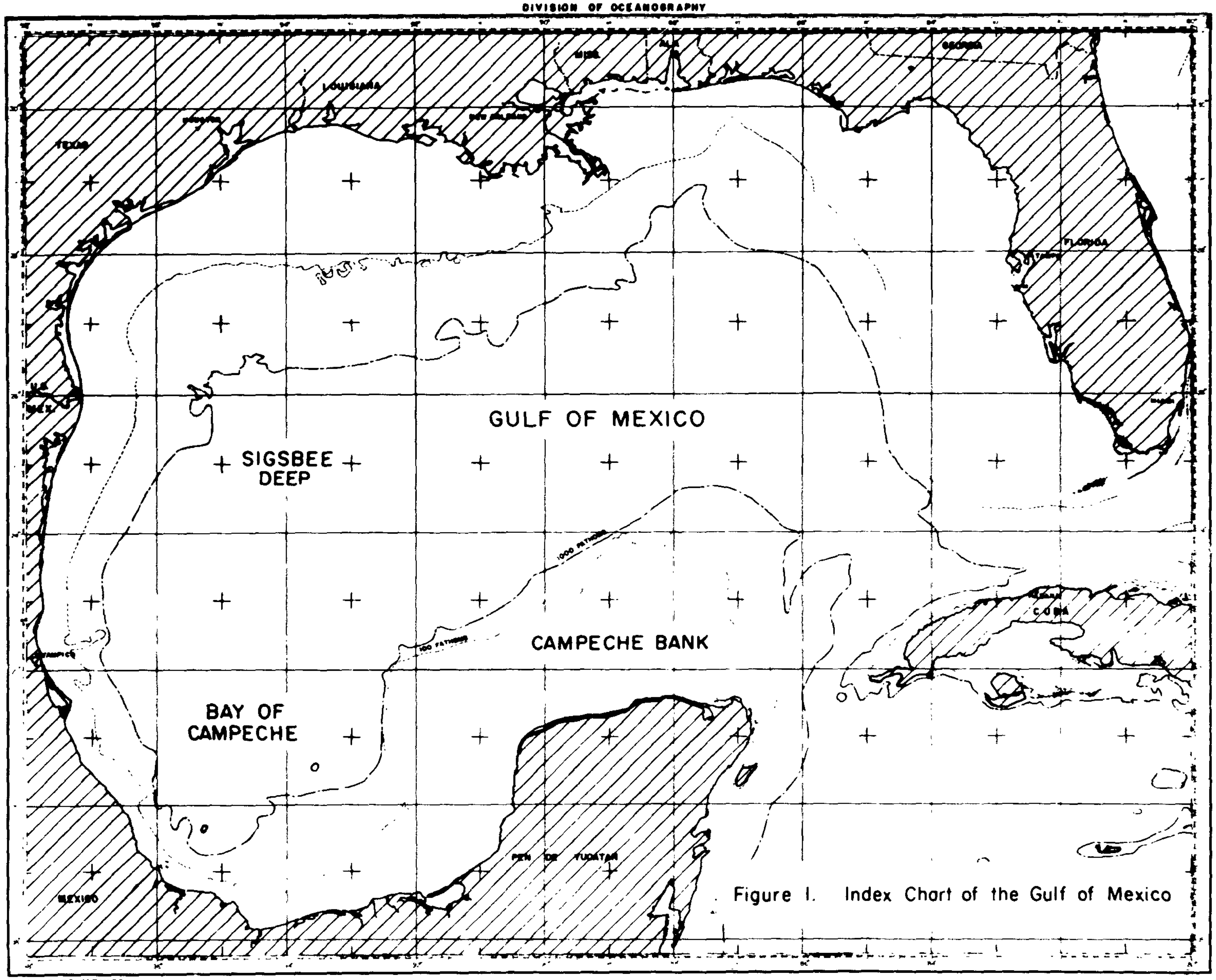

Figure I. Index Chart of the Gulf of Mexico

GULF OF MEXICO
FROM USC&GS 1007

sidered as a part of the reconnaissance stage of the study of the Gulf of Mexico.

The soundings that serve as a basis for this research were gathered from various sources. The major bulk of the data were obtained from unpublished smooth plotting sheets produced from soundings taken by the Hydrographic Survey Group under the Command of the USS Tanner during the winters of 1949, 1950 and 1951. Soundings were also taken from Hydrographic Office Charts 2056 (East Coast of Mexico) and 1295 (Bahia de Campeche) and from United States Coast and Geodetic Survey Chart 1007 (Gulf of Mexico). These charts were compiled by the above two authorities from original surveys by the United States Coast and Geodetic Survey, Hydrographic Office, U. S. Navy, British Admiralty, and American Geographical Society. To these were added data taken from fathograms made aboard the U. S. Fish and Wildlife Research Vessel, Alaska, while on cruises to the southern Gulf of Mexico.

B. Location of the Bay of Campeche

The Bay of Campeche is a broad southern lobe of the Gulf of Mexico (Figure 1, pg. 2). It is enclosed roughly by longitudes 90°W and 98°W and latitudes 18°N and 22°N. At the north the Bay merges widely with the Gulf of Mexico. The Bay of Campeche is bounded counter-clockwise by the Mexican states of Veracruz, Tabasco, Campeche and Yucatan. Because this "bay" is not at all enclosed, some maps do not differentiate it from the Gulf of Mexico.

The broad depression which has long been termed the Sigsbee Deep is the deepest portion of the Gulf of Mexico. This deep lies along the central part of the imaginary northern boundary of the Bay of Campeche. Soundings show the depths to be greater than 2100 fathoms in the vicinity of longitude 94°W and latitude 23°N. International committees have recommended calling this depression the Mexican Basin. (Informal committees advisory to the geographic boards of United States and British map making organizations. Reports have been informal and are as yet unpublished.)

C. Previous Investigations

To the knowledge of the writer, there have been no detailed investigations into the geologic nature of the bottom of the Bay of Campeche seaward of the edge of the continental shelf. However, there have been numerous studies of the areal geology of the bordering coasts with some speculation on the outlying continental shelf. Larger contributions covering the regional historical and structural geology of the Gulf of Mexico have appeared frequently since Eduard Suess (1888) first gave us the idea that the Gulf was formed by the collapse of the foreland of the Antillean cordillera and that its

outline was not influenced in any visible manner by the course of the mountain folds.

The only treatise on the general geology of the American Mediterranean is that by Charles Schuchert (1935). More recently the knowledge of the coastal plain, shoreline, and continental shelf of Mexico has been furthered by excellent studies by Manuel Alvarez, Jr. and Frederico Mina (1951), V. R. Garfias and T. C. Chapin (1949), W. Armstrong Price (1953), and J. L. Tamayo (1949). Recently ideas on the historical and structural geology of the Gulf of Mexico have been advanced by W. H. Bucher (1941), A. J. Eardley (1951), W. Armstrong Price (1951), J. H. F. Umbgrove (1947), and Paul Weaver (1950). These are currently summarized by S. A. Lynch (1953MS).

D. Acknowledgments

The author wishes to express his sincere appreciation to W. Armostrong Price for his direction and the time he has spent in conference with the writer. His suggestions and criticisms have been most helpful and his interest in this study has been very encouraging.

Additional thanks are due Warren C. Thompson who was ever willing to discuss any problem that arose and who was responsible for the original discussion that started the writer in search of answers to some of the problems dealt with in this thesis. The writer is indebted to Charles C. Bates who helped in securing information and to Paul Weaver for reading the manuscript and offering many valuable suggestions.

Acknowledgment is made to the U. S. Navy Hydrographic Office which supplied certain soundings without which this study could not have been completed. A final debt of gratitude is owed by the author to his wife, Barbara, for here careful drafting of the accompanying figures and chart.

This study was supported by contract between the Texas A & M Research Foundation, the Office of Naval Research (N7onr-48702) and the Navy Hydrographic Office.

II. SURROUNDING AREAL GEOLOGY

Such features of the geomorphology and structural geology of the landmass bordering the Bay of Campeche as have a bearing on the submarine geomorphology will be discussed as an introduction to the submarine study.

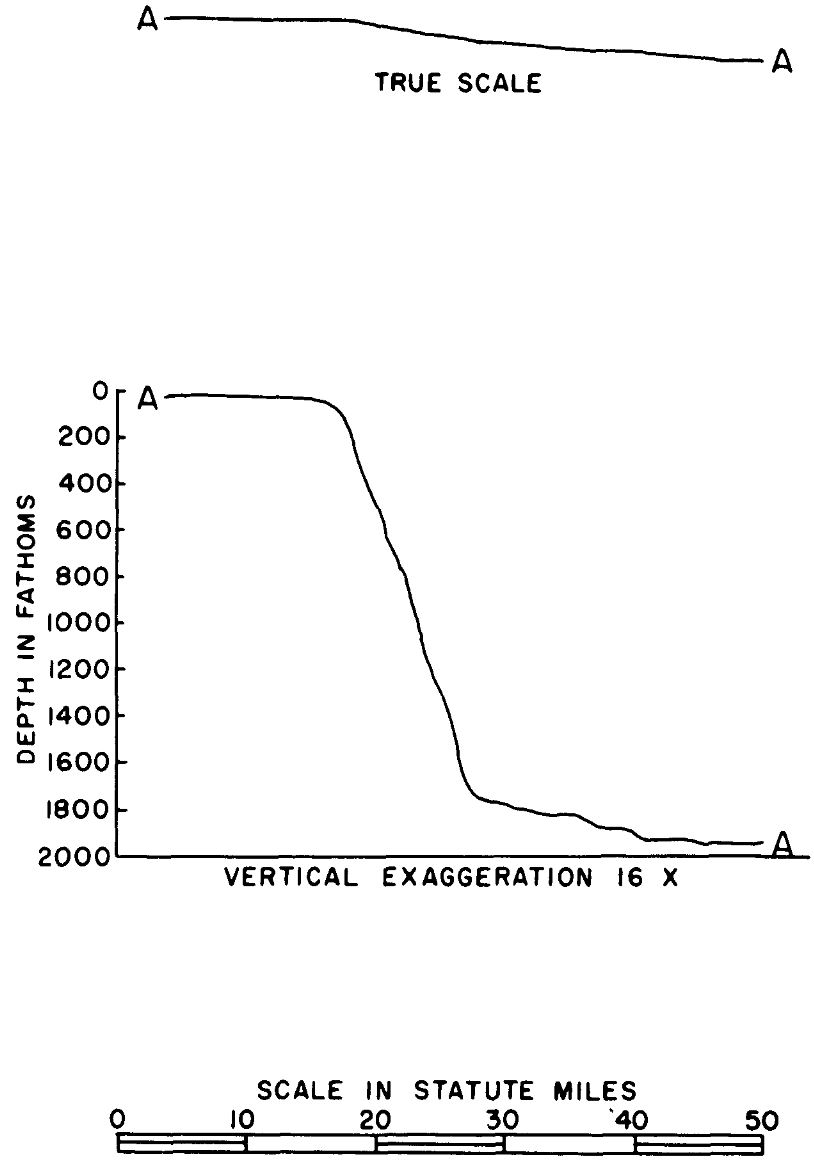

Figure 2. Profile of the Continental Slope and Portions of the Adjacent Continental Shelf and Bay Bottom along 92° West Longitude off the North Campeche Bank. (For location of A-A see Chart in Pocket.)

The most prominent features of the bordering landmass are the the coastal plain and continental shelf which are broad on the east and narrower on the west. For simplicity the continental shelf will here be assumed to have the same general characteristics as the adjacent coastal plain.

The outline of the Bay of Campeche, which is semicircular, is controlled directly by the surrounding structures. The shoreline, which is striking southward along the western margin of the Bay, is forced to curve southeastward first by folds of the Eastern Sierra Madre, west of Tampico, and then by the Neo-Volcanic Cordillera of Southern Mexico. The Sierra Madre structures trend into the coast at an angle of about 25°. The volcanic rocks project toward the east. Price (1953) states that the shoreline is curving to adjust to these two trends which combine to produce the curve. The shoreline again trends nearly N-S along the west coast of the Yucatan Peninsula which is believed to be a unit horst with minor fault blocks. Therefore the major structure of the Bay is a concordant basin in that the shorelines in general strike parallel with the major structural lines of the adjacent coast.

The coastal plain extends around the Bay of Campeche as a virtually unbroken band with maximum widths of 210 miles across the Yucatan Peninsula, 70 to 100 miles in the Isthmus of Tehuantepec at the southern end, and 150 miles near Tampico at the west. The narrowest parts are at the southwest where the Volcanic Province intersects it almost pinching it out completely. In general the coastal plain is inclined toward the sea with slopes ranging from 10 feet/mile to less than 2 feet/mile. The coastal plain is interrupted near latitude 20°N northeast of the city of Jalapa where volcanic rocks of the Southern Volcanic range or zone (Sierra Neo-Volcanica of Tamayo 1949) with structures east of the Sierra Madre form a broad projecting coastal salient. Another salient of similar size is formed by the disconnected volcanic mass of the Sierra de los Tuxtlas with many minor projecting points along shore. This lies just northwest of Puerto Mexico (Coatzalcoalcos).

The coastal plain from the Volcanic Province to the Yucatan Peninsula is composed of extensive rain-forest swamp on deltaic deposits. According to Price's classification of shorelines and coasts (1953) the entire area from the Laguna de Terminos (90°40'W Longitude) west to Puerto Mexico is of arcuate delta form, composed of the delta plain of a group of large rain-forest streams.

The NW portion of this southern area, in the southern part of Vercruz, has numerous salt masses and salt domes (Alvarez and Mina, 1951) one of which has been discovered under the shelf. Submarine ridges on the sea floor in this area have been called salt anti-

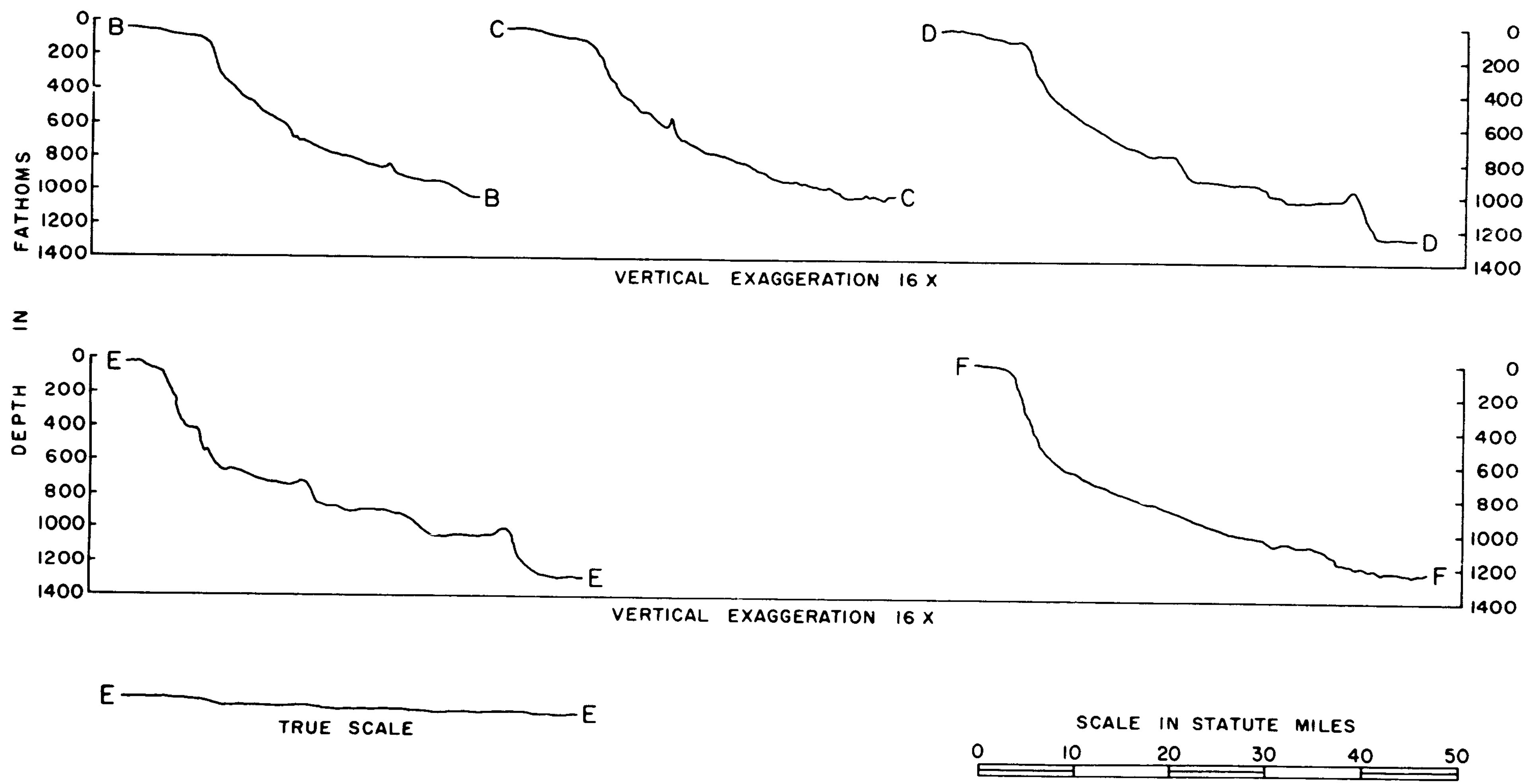

Figure 3. Profiles of the Continental Slope and Portions of the Adjacent Continental Shelf and Bay Bottom off Veracruz. (For locations of B-B, C-C, D-D, E-E, and F-F, see Chart in Pocket.)

clines. Both great faults (Weaver, 1951) and folds (Alvarez, 1949) strike the coast at an angle in this region.

The Peninsula of Yucatan is, in effect, almost featureless for the purposes of this paper. It is an extensive, almost flat, limestone 'slab' that rises very little above sea level. It appears to be a huge horst which is the major structure of the entire peninsula. The horst is flanked by major arcuate folding on the east. On the west there is a minor fold or fault-block at the coast between Champoton and the town of Campeche.

Heavy earthquakes are common in the mountains and volcanic areas, but only light shocks are reported for the immediate coastal areas. No authenticated submarine seismic activity is reported in the Bay. San Martin Tuxtla (near Roca Partida) has been slightly active twice in historic time. It is only 10 miles from the Bay, the closest known recently active vent. Faults and folds are known on the shelf as previously noted. Steep scarps bordering the Yucatan Peninsula indicate large faults there. Unconfirmed reports of shoals off the shelf in the Bay of Campeche may be disregarded until substantiated by further soundings (Price has dropped his former, 1951, interpretation of various unconfirmed reports that there may be volcanic peaks in the Bay, that one was active in 1904 and that igneous rocks occur in western Yucatan).

III. BATHYMETRY

A. Contouring

Because of the scarcity of published information on the bathymetry of the Bay of Campeche the writer had no conscious preconceived ideas on the outcome when the mechanical process of contouring the collected soundings was begun. The second and succeeding contourings, however, contain interpretations made by the writer. The interpretations will be brought out in the discussions of specific areas.

The contour interval of 100 fathoms chosen for the map (Pocket) may appear too large but, it was necessary to use this interval so that the areas of both dense and lean data might be covered uniformly. The contours themselves are broken down into three classifications: (1) solid contours are those constructed in areas where the density and reliability of soundings are sufficient to give results with little if any interpretation; (2) dashed contours are those through areas of scattered soundings which are necessarily placed with some interpretation; and (3) alternately dashed and dotted contours are those that pass through areas of no data which, therefore, are entirely interpretive.

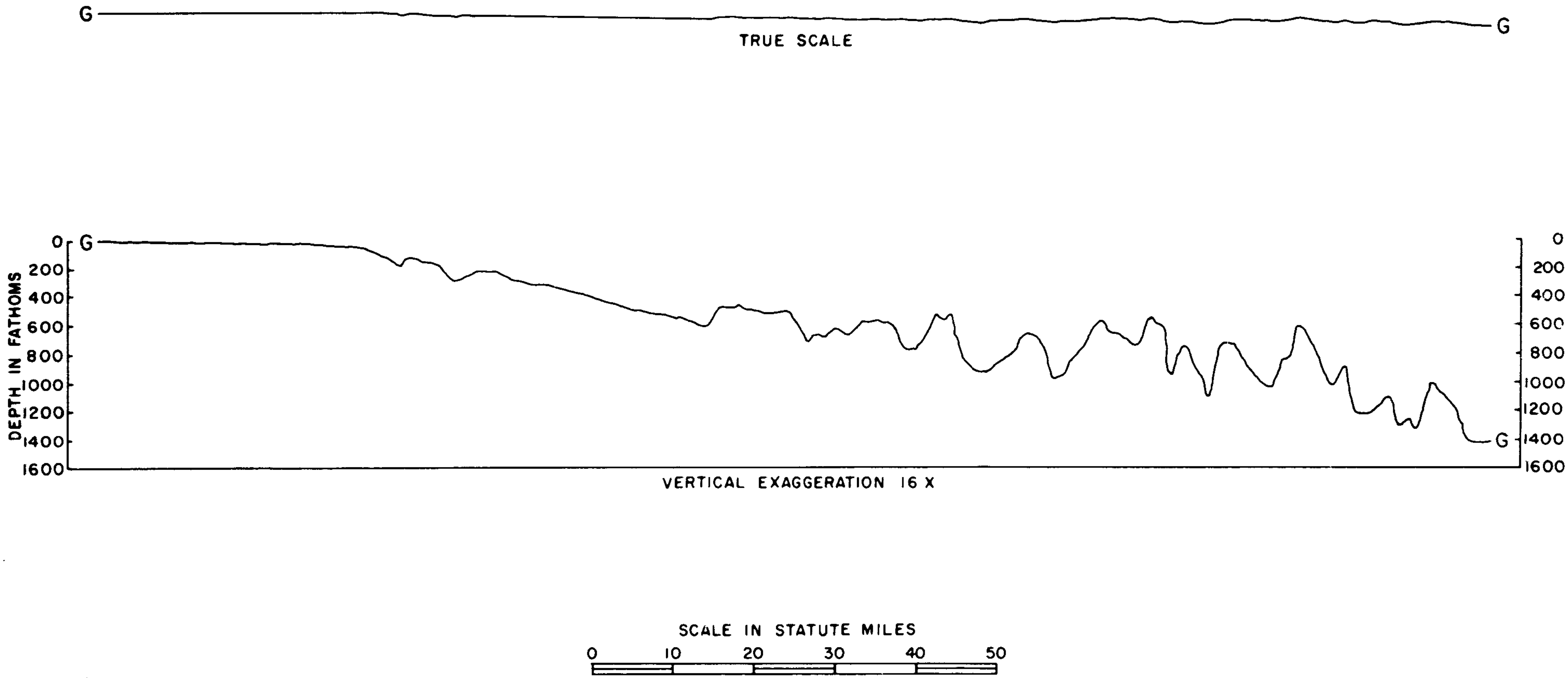

Figure 4. Profile of the Continental Slope and Portions of the Adjacent Continental Shelf and Bay Bottom along 94° West Longitude off the Grijalva Delta Area. (For location of G-G see Chart in Pocket.)

Numerous factors regarding the reliability of soundings and resulting contours must be kept in mind. The soundings taken in the earlier surveys were by lead line which has not been considered as accurate under most conditions as modern sonic methods which continuously record the bottom configuration. Positioning the soundings by astronomical fixes was probably comparable on both early and late surveys. However, dead reckoning can be considered to have a higher degree of accuracy on modern surveys since sailing vessels were laregly at the mercy of the variations of the wind. Therefore an earlier sounding was discarded for a modern sounding in cases of conflict. Those soundings in dense sounding areas were considered more reliable than scattered soundings because in the dense areas adjacent soundings serve as a check on each other. Soundings near islands or within sight of land are given added reliability because of the increased ease in positioning of these points. The soundings positioned out of sight of land were placed by astronomical fixes and/or dead reckoning, and are probably not more accurate than plus or minus one mile. Where intersecting or adjacent lines of soundings consistently show large contrasts in depth or an artificial looking 'zig-zag' topography, errors in position are indicated. In some cases such errors are too large for useful adjustments to be made.

B. Description of Topography

Five provinces or sectors of the Bay of Campeche are covered by this thesis (see chart in pocket). The first four cover the continental slope. They are: Tampico Province — between Tampico and Pt. Delgada; Volcanic Province — between Pt. Delgada and an imaginary line connecting the point at which 94°W Longitude intersects the coast and the intersection of 95°W Longitude and 20°N Latitude; Grijalva Delta Province — between the eastern boundary of the last province and the point where the 100 fathom isobath intersects 21°N Latitude; NE Orogenic Province — between the northeast border of the last province and the intersection of the 100 fathom isobath and 92°W Longitude. The fifth province is the Basin of the Bay of Campeche which lies offshore from the four provinces already described.

The seaward boundary of the continental shelf is marked all around the Bay of Campeche by a change (steepening) in bottom slope which, off the west and north coasts of the Yucatan Peninsula and off Veracruz is very abrupt. This change occurs rather uniformly at a depth of 100 fathoms except in profile F-F (Figure 3, pg. 7) where the steepening occurs at 40 fathoms. This abrupt change is best seen (Figure 2, pg. 5) off the north side of Campeche Bank in a profile (A-A) running N-S along 92°W Longitude and trending normal to the strike of the continental slope. The slope of the bottom of the shelf from shore to a depth of 50 fathoms averages 3'/mile (0°02'). From here to the 1700 fathom isobath on the continental slope the gradient averages 1000'/mile (10°45'). This gradient then flattens rapidly to join the essentially flat bottom of the Gulf of Mexico.

The character of the continental slope off the Volcanic Province (Figure 3, pg. 7) is strikingly different, although the steepening at the shelf edge and its abruptness are comparable to the last described break. The profiles of the continental slope in this area have a definite concavity with an upper steep slope descending to variable depths between 400 and 650 fathoms, followed by a more gentle lower slope to the bottom of the Bay. Each of the profiles drawn indicate a slight steepening at the 40 fathom level, the change being pronounced in profile F-F. The gradient of the shelf from shore to the 40 fathom isobath averages 13'/mile (0°08'). Then there is a slight increase in the gradient to the 100 fathom isobath (with the exception of profile F-F) at which point the abrupt steepening occurs and the gradient increases to 760'/mile (8°11'). This figure is taken from E-E but is representative of all the profiles. This gradient becomes more gentle below 400-650 fathoms with an average from this point seaward of about 136'/mile (1°30') or less. The overall gradient of the continental slope averages 157'/mile (1°42').

The offshore slope of the Grijalva Delta Province (Figure 4, pg. 9) is much less distinct. Landward of the break which lies between 40 and 50 fathoms the gradient averages 11'/mile (0°07'), and seaward the average is 61'/mile (0°40').

The width of the continental shelf is highly variable. At Tampico the width is 120 miles. Southward, the shelf narrows sharply to about 8 miles off Roca Partida, 35 miles east of Alvarado. Northeast from Roca Partida the shelf widens to a maximum value of 130 miles off Palmas Point on the NW coast of the Yucatan Peninsula.

Tampico Province

The data for the Tampico Province are so scanty that few details may be described. Perpendicular to shore off the city of Tampico is a steep-sided ridge that extends some 35 miles beyond the edge of the shelf. This ridge is outlined by the 100 fathom isobath with some probable peaks the shallowest of which reaches to within 5 1/2 fathoms of the surface. The maximum relief off the eastern end is 950 fathoms. The other feature, which lies to the southeast of Tampico, is less well known. As mapped on Chart 2056, U. S. Hydrographic Office, its shallowest depth is 73 fathoms and its relief is 200 fathoms. Both of these features are somewhat doubtfully reported to have been confirmed by later surveys.

Hydrographic Office Chart 2056 also shows a large protuberance in the 100 fathom isobath (dotted on the enclosed chart) just to the northeast of Pt. Delgada. This disappears when the new information is added. The seaward portion of this nose can be confidently removed because of the course of the reliable 600 fathom isobath. The remainder of the nose is smoothed by interpretation.

The contours within the area enclosed by longitudes 96°W and 97°W and latitudes 21°N and 22°N are drawn entirely by interpretation as is seen by their alternately dash-dot character. They were drawn essentially parallel to the coast line and the somewhat more reliable seaward contours. This interpretation is based on scattered soundings found on the northern and southern borders of the area is in agreement with the character of the continental slope immediately to the south.

Volcanic Province

The continental slope of this province narrows somewhat and has an irregular topography. Numerous shoals have been reported here in deep water, but only the one shown off Veracruz is reported to have been confirmed. This shoal has previously been interpreted as a ridge but is here shown as a peak only, since, within the accuracy of positioning, deep water passes between the shoal and the edge of the shelf. Contouring difficulty encountered in this area was due to a difficulty in adjusting conflicting parallel sounding lines that were produced on separate dates. Therefore, although there appear to be indications of submarine canyons on the slope here they must be viewed with caution because of possible residual sounding line errors.

Profile E-E (Figure 3, pg.7) has three distinct benches on the lower portion of the continental slope, two of which are flat. The higher one lies between 680 and 740 fathoms with a gradient between these two depths of 63'/mile (0°41'). The middle bench lies at a depth of 900 fathoms and is flat for a distance of 3.6 miles. Below this bench the gradient increases uniformly, reaching an average of 156'/mile (1°42'). At a depth of 1040 fathoms it flattens out again for a distance of 6.8 miles forming the bottom bench. These benches may also be seen in profile D-D (Figure 3, pg.7), which lies just to the north, although the upper bench is not too distinct. Slight benches are also seen in profiles B-B at a depth of 960 fathoms, C-C at depths of 930 and 1030 fathoms, and in F-F at depths of 1080 and 1240 fathoms.

Grijalva Delta Province

The continental slope here widens to over 100 miles. The topography is characterized by its irregularity and high relief. As is seen from the contoured chart (Pocket), the data along the outer margin of the slope and along the meridian of 94°W Longitude permitted detailed delineation of the topography. This delineation permits the writer to extend his interpretation to the remainder of the province. The gulfward margin, when contoured mechanically has a highly irregular topography with a high to the east reaching upward to 720 fathoms, a maximum seaward relief of 300-400 fathoms and a minimum landward relief of 100 fathoms. To the west is a similar high with the shallowest points at 600 fathoms, a maximum relief of 600 fathoms and a minimum

of 200 fathoms. Both of these highs have ENE-WSW trending axes. The high to the west contains two basins or troughs in the central portion along a line that lies normal to the axis of the high. The seaward basin reaches a depth of 1100 fathoms and the landward basin a depth of 1075 fathoms giving the former a relief of 475 fathoms and the latter a relief of 260 fathoms. Three valley-shaped features serve to separate the highs and limit their NE and SW ends.

The profile (G-G, Figure 4, pg. 9) taken from a continuous fathogram along 94°W Longitude also indicates a highly undulating bottom. From the edge of the continental shelf out to a depth of 600 fathoms the bottom has a fairly uniform gradient of 78'/mile (0°51'). This smooth slope is interrupted in two places near the shelf edge by depressions with relief of 80 fathoms each. Seaward of the 600 fathom isobath the gradient is reduced to an average 52'/mile (0°34'). This portion of the slope consists of a series of rises and depressions with maximum relief of 440 fathoms.

Along the eastern margin of this province the slope which had a trend of ENE-WSW bends sharply northward assuming a N-S strike along longitude 92°30'W. This marginal zone can best be included in the description of the NE Orogenic Province.

NE Orogenic Province

The continental slope in this province is part of one of the great scarps of the Gulf Basin recently discussed by Weaver (1950). This scarp has a gradient of 1000'/mile (10°45') and seems to have a steep smooth slope down to a depth of 1700 fathoms. From this depth seaward to the almost flat Gulf bottom at 1940 fathoms the gradient is reduced to 80'/mile (0°52') and the bottom is gently undulatory. On the west side of Campeche Bank the edge of the shelf lies at approximately the same depth as in profile A-A (Figure 2, pg. 5), but the steep gradient does not begin until the 200 fathoms isobath is reached. The base of the steeper gradient occurs at a higher level than in profile A-A, ending between the 1200 and 1300 fathom level. The steeper gradient extends southward into the Grijalva Delta Province but with a reduced value and a base at a depth of only 800 fathoms. The gradient is reduced to less than 1° as the trend of the slope turns toward the west.

The seaward edge of the continental slope in the Grijalva Delta and NE Orogenic Provinces is indicated by an abrupt change (reduction) in slope as was the case (increase) with the outer edge of the continental shelf. This break in slope is not generally seen in the Volcanic Province but may be present locally, as seen in Figure 3, profiles D-D and E-E (pg.7). As the margin of the continental slope is approached, a definite steepening is seen in the profiles of the three provinces, ending in the almost flat bottom of the Gulf of Mexico. The base of the continental slope lies at different depths

at the three places described, with the deepest slope margin in the NE Orogenic Province and the shallowest in the Volcanic Province. This steeper slope or escarpment in the NE Orogenic Province lies between 1500 and 1700 fathoms and has a gradient of 1337'/mile (14°12'). The escarpment in the Grijalva Delta Province lies between 1170 and 1420 fathoms and has a gradient of 1003'/mile (10°45'). The possible local escarpment in the Volcanic Province lies between 1040 and 1220 fathoms and has a gradient of 885'/mile (9°30'). Seaward of these escarpments the gradient of the bottom is essentially flat continuing out into the Gulf of Mexico on slopes of about 19'/mile (0°12'). Although profiles B-B, C-C, and F-F (Figure 3, pg. 7) may seem to have a slight terminal escarpment, they generally approach the surface of the bottom of the Bay tangentially. The portion of the bottom of the Gulf of Mexico that extends into the Bay of Campeche is featureless, as seen on the contour chart (Pocket), except for the one basin (?) at 95°15'W Longitude and 22°20'N Latitude which has a relief of 100-200 fathoms.

C. Geomorphic Interpretation and Discussion of the Results

For purposes of discussion the Bay of Campeche was divided into provinces since it does not readily lend itself to one overall interpretation. The provinces were so named for the following reasons: (1) Tampico Province -- this province cannot be given a name with any connotation as to its origin because of the sparsity of reliable soundings; (2) Volcanic Province -- so named because volcanism and associated diastrophism appear to have played a roll in controlling the bottom configuration in this area; (3) Grijalva Delta Province -- extensive sedimentation here has been a controlling factor in the development of the topography; (4) NE Orogenic Province -- the uplift of the Yucatan horst appears to have produced the major feature here; and (5) Basin of the Bay of Campeche -- this province is the remaining area seaward of the continental slope.

Tampico Province

The only interpretation feasible in this province is that regarding the origin of the extensive transverse ridge which extends out onto the slope off Tampico. The ridge is referred to as a "large submerged mountain range" by Price (1953). With the limited information available in this area the writer can at best just present the two most likely interpretations. This ridge may be either formed by a series of originally disconnected volcanic peaks that have been joined by outpourings of lava or it may be a remnant of the floor of the Gulf left standing as the floor was downfaulted.

The slope in this area is expected to exhibit some of the same general features as seen off the Grijalva Delta as further investigations are carried out. These features will undoubtedly not be as extensive, if found, because the deltaic areas south of Tampico - mostly off Veracruz - are small in comparison with the Grijalva Delta. The fact that any peak-like features seen off Tampico may be of volcanic origin cannot be overlooked because one of the striking geologic features of this area is the number of volcanic plugs and other igneous hills present (Ordonez, 1936, Geologic Map of North America).

Volcanic Province

The continental slope in this province is steep (8°11') and narrow (about 25 miles). These facts when coupled with the presence of an adjacent orogenic coast suggest that diastrophism has determined the overall character of the slope. The lack of any great amount of sedimentation in the area until possibly Pleistocene time (Price, 1951) has made it possible for this narrowness and steepness to remain essentially unchanged.

The lesser features, particularly the benches prominent in profiles E-E and D-D (Figure 3, pg. 7), may indicate another controlling factor in the formation of the bottom topography. On profile E-E there is a slight bench at the edge of the continental shelf just before the abrupt change in slope, then a steep slope followed by a series of minor irregularities and another bench followed in turn by two more sets of benches with steep slopes both to seaward and landward. Since this province lies offshore from and in an approximate line with the E-W Volcanic Province of Mexico these benches could possibly be tied in with the adjacent volcanism and accompanying diastrophism. They can be explained either as formed by lava laid down in place or as a step-faulted lava plain that was originally at a shallower depth. The escarpments on either side of the benches tend to favor a diastrophic origin for the placing of the benches. However, further investigation with numerous cores from the escarpments will be needed before this idea can be given any validity. Although minor benches can be seen on the other profiles they do not appear to have a direct connection with the larger benches just described which illustrates that the horizontal extent of any one bench is limited.

Slumping which is thought to be a major control of the topography to the east of this area may also play a major roll in the development of the topography of this slope. The irregular portion just below the steep inner margin of the slope as seen on profile E-E (Figure 3, pg. 7) may be due to slumping caused by a possible overloading by lava at the continental shelf edge. Price (1951) also holds to the beliefs that "This shelf is probably, in part, fragmented by diastrophism" and possibly heavy loads of volcanic materials

helped overload the shelf areas. This slumping may be a factor that limits the horizontal extent of the benches. The irregularity at the base of the upper steep slope, which has been attributed to slumping, is seen only in profile E-E which is also the profile that exhibits the best developed benches. Profile D-D has the two lower benches well represented but the upper bench is obscure. Slumping may account for this also if the material involved, instead of stopping at the base of the steep slope, producing an irregularity at this point, continued on seaward spreading out uniformly thus tending to hide the upper bench. The virtual absence of benches on the other profiles may also be due to this process, either by the occurrence of large amounts of material involved in the slump or by slumping initiated below each bench due to an overloading by the lava forming the bench.

The overall lack of irregularity in the profiles (Figure 3, pg. 7) in relation to the adjacent area to the east may, in part, be due to the sparsity of sediment available to this area. This lack of sediment is brought about by the proximity of large mountain ranges on two sides and the fact that until recently the southern portion of Mexico was a region of large basins of internal drainage. Even if fairly large amounts of sediment had been available, the slope might not have been smoothed against the factors of steep slope present and diastrophism which is known to have been recently active in the nearby E-W Volcanic Province.

The one peak that has been retained as confidently placed on the slope (27 miles off the city of Veracruz) is interpreted as being of volcanic origin. Its relief which is on the order of 3500' places it out of the salt intrusion classification to the writer's way of thinking. The fact that soundings have been placed all around this peak that do not show flank depths indicates that the horizontal extent is limited. This fact tends to remove the possibility that the peak is a linear compressional feature. It is entirely possible that other peak-like features may be present in this province. There are a number of areas of limited sounding coverage where a peak may be present.

Grijalva Delta Province

This province has been subjected to the greatest amount of speculative interpretation. Therefore, this portion of the chart (Pocket) has been retained as it was first mechanically contoured so as to allow the reader to interpret what he believes to be most likely. The contour chart as it stands indicates two broad highs and a number of minor depressions. The profile (G-G, Figure 4, pg. 9), however, which was taken from a fathogram, shows the highs and depressions to be much more numerous than indicated by the contours along the outer margin of the slope. The sounding lines which provided the information used in contouring the outer margin of this slope, and thus produced the linear highs shown, run parallel to the strike of the highs. The

suspicion was immediately aroused that the linear trend was due, at least in part, to errors in scale along lines of soundings that all run in the same direction. Therefore these linear highs are possibly anomalous. The writer believes that the sinuosity of the contours plus the undulations seen in the profile indicate a bottom topography very similar to that found by Treadwell (1949) on the continental slope in the NW Gulf of Mexico. These indications all add up to the idea that the topography here is composed of closed basins, ridges, and knobs (canyons and escarpments which may be present must be left for determination by future investigators) which probably would be seen to be of much less horizontal extent than indicated by the contours if more information were available.

This type of topography, which the writer considers to be characteristic of this province from the present data, appears to extend the entire length of the province and from the escarpment along the outer margin into a depth of 600 fathoms. There are two reasons for assigning this extent. First, the width is indicated by the profile (G-G, Figure 4, pg. 9) which runs essentially normal to the strike of the continental slope, and the contours along the seaward margin of the slope give an indication of the length. Second, the dashed contours on the remainder of the slope have a highly sinuous character rather than being straight and running generally parallel to the coast. This suggests an uneven topography rather than a smooth slope.

In this province the continental slope reaches its maximum width. Tamayo (1949) and Price (1951) have held that the large deltaic plain to the south indicates that the continental margins have been substantially projected seaward by sedimentation. Neither of the adjacent provinces show good signs that any large degree of sedimentation has been active in the past or is active at present. Therefore, the greater portion of this large supply of sediment must have been deposited at the continental margin in this province. As this sedimentation continues along the continental shelf margin an unstable condition must result because of the absence of any retaining feature to seaward. The process by which this unstable condition is relieved is probably also responsible for the topography found today on the continental slope.

The relief of the unstable condition and the basins, knobs, and ridges that characterize most of the bottom configuration and their presence at known depths at no less than 600 fathoms may be explained as a result of faulting, isostatic adjustment, slumping or any combination of these. Russell (1936) attributes the differential subsidence of sub-delta portions of the Mississippi Delta to isostatic adjustment brought about as a result of overloading of the crust of the earth by the delta sedimentation. From Fisk's (1944) fault-line map of the delta area, however, it would be possible to conclude that this subsidence might be connected with movements of fault blocks. These processes may also be applicable to the Grijalva Delta Province since they would tend to remove the unstable situation and could produce the topography present.

Subsidence due to isostatic adjustment requires that the area have a sufficient overburden which appears to be present. Faulting as a cause of the observed conditions is also plausible. Certainly sufficient diastrophic activity is known in the area or may be extrapolated into the area. An escarpment is present along the outer margin of the slope providing definite proof of activity. The continental slope in this province lies on a line projected from the general strike of the E-W Volcanic Province of Mexico and the Volcanic Province of this report. If the volcanism actually extended to this province then a further diastrophic activity factor may be postulated. However, no signs of volcanic activity have been noted in this area (i.e. no volcano-like peaks or extensive flow-like areas are discernible).

The writer does not believe that either of the first two mentioned processes can account for the exceptional width of the continental slope plus relieving the unstable condition and producing the observed topography. The slumping process is preferred. All three of the conditions are met by the process of large masses of sediment slumping from the edge of the continental shelf which in turn produces folding and faulting in the agitated areas. This would also account for the elongate features on the outer margin of the continental slope since compression produced by slumping would act in a direction normal to the margin. The fact that large amounts of sediment may be transported long distances has recently been given strong support by Heezen and Ewing (1952) — "The large scale movement after the Grand Banks earthquake serves as overwhelming proof that currents do occur which will transport large amounts of sediment far out into the ocean basin." The currents mentioned by Heezen and Ewing are believed to have been generated by slumping which affected an area 80 by 150 miles along the continental slope.

The only other area in the Gulf of Mexico exhibiting these unusual topographic conditions is that offshore from Texas and Louisiana. The same type of topography was found (Treadwell, 1949) on the continental slope here as the writer finds in the Grijalva Delta Province. Treadwell also suggests slumping, folding, and faulting as the cause of the slope topography. He believes, however, that "diastrophism is probably the only agent that could produce closed basins of the type and magnitude common in the area." The presence of the escarpment at the seaward edge of the continental slope which is interpreted as a fault scarp suggests that there has been recent diastrophism in the area. This activity may possibly have been the triggering action setting off the slump and may have continued during and after the slumping, thus aiding in the formation of the closed basins, knobs and ridges.

<u>NE Orogenic Province</u>

The continental slope in this province is the simplest in character and gives the least difficulty in interpretation. At the scale

used in this study, the slope appears uniform. With the data available at present the profile (A-A) in Figure 2 may be taken as representative of the entire continental slope in this province. The extremely narrow width of the slope (10 miles at the profile location), its sheer drop (10°45') to depths of 1700 fathoms, and its smoothness are hard to explain any other way than by orogeny. The slope is interpreted as a fault scarp which bounds the probable Yucatan horst (Price, 1951). The steepening of the scarp along the base of the slope may indicate a more recent diastrophic activity.

The escarpment that forms the eastern margin of the Grijalva Delta Province is an extension of the scarp to the north which has already been discussed. One interesting feature that appears on this extension is the sudden change in direction of the upper margin of the slope from a N-S to an ENE-WSW trend. This curve alone is not difficult to explain since the uplift of the Yucatan horst across the normal trend of the coast would create a sharp bend. However, the change in trend lies directly offshore from a similar protuberance in the coast line of Yucatan. Price (1953) classifies this portion of the shoreline and coast as "Fault block, tilted or upthrust (horst), scarp or scarps run inland." The similarity of the onshore and offshore features leads to the interpretation that there is a possible zone of cross faults (en echelon) that extends out to the continental slope at this point.

The lower portion of the continental slope also exhibits a sharp westward bend. Just after the scarp crosses the 21st parallel, the portion below 1000 fathoms changes its strike from N-S to E-W. The gradient of this part of the slope is maintained around the bend, therefore, this E-W trending scarp is also considered a fault scarp. This scarp is probably the result of cross-faulting and may have a relationship with the scarp bend in the upper portion of the continental slope that occurs farther to the south.

Basin of the Bay of Campeche

The bottom of the Bay of Campeche north of the continental slope appears to have a smooth, gentle, gulfward slope towards the Sigsbee Deep. The only interruption in this even topography is the possible basin at 95°15'W Longitude and 22°20'N Latitude which has an indicated relief of only 100-200 fathoms. The conclusions reached in this study tend to make the writer follow Paul Weaver (1950) when he "-- proposes the theory that the Gulf of Mexico as a deep sea is young, and that its present central great depth is due to down-faulting, localized most intensely along the continental slope west of Florida and the slope adjacent to Yucatan, and that along these major lines the greatest single displacement took place, but that even where the continental slope is less steep, it is a zone of faulting, possibly at several periods." This theory is supported by the presence of the escarpment along the outer margin of the continental slope which

suggests recent downfaulting of the seaward portion. The appearance of a strong, definite scarp off Yucatan and the Grijalva Delta and the local nature of scarp lengths toward the west off the city of Veracruz indicate that the movement increases from west to east. A statement by Tamayo (1949) concerning the Yucatan Peninsula also tends to support this view. "Emergence is still perceptible, as may be seen at Progreso, where in 88 years the sea has retreated 200 meters" (translation by the writer).

IV. SUGGESTED CRITICAL AREAS FOR FUTURE INVESTIGATION

To complete the data necessary to contour the bottom of the entire Bay of Campeche and its margins, many soundings are obviously needed. To test the geological interpretations of the striking features of the Bay made by the writer and others, it is desirable to have cores from certain critical areas.

For example, more data are obviously needed in the Tampico Province and in the Basin of the Bay of Campeche. There are almost no published data on the Tampico Province, so that any additional data will be a contribution here. There are abundant soundings for the western sector of the Basin of the Bay of Campeche, but they were all taken along parallel lines, giving anomalies that have not been satisfactorily corrected. A number of lines of soundings running NW-SE across this area would be most helpful. The eastern sector is another area of very scanty data.

The Volcanic Province presents a different problem. Here the data are adequate but to use them to best advantage it will be necessary to obtain cores from which the validity of the interpretations made in this report may be tested.

More data in the Grijalva Delta Province, particularly in the SE portion, are desirable. Also more sounding lines running normal to the strike of the continental slope are needed to correct the suspected anomalies in the present data.

Before it will be important to produce more soundings in the NE Orogenic Province, it would be advisable to obtain cores from the face of the continental slope. These cores would aid greatly in testing the interpretation that the slope is a fault scarp face.

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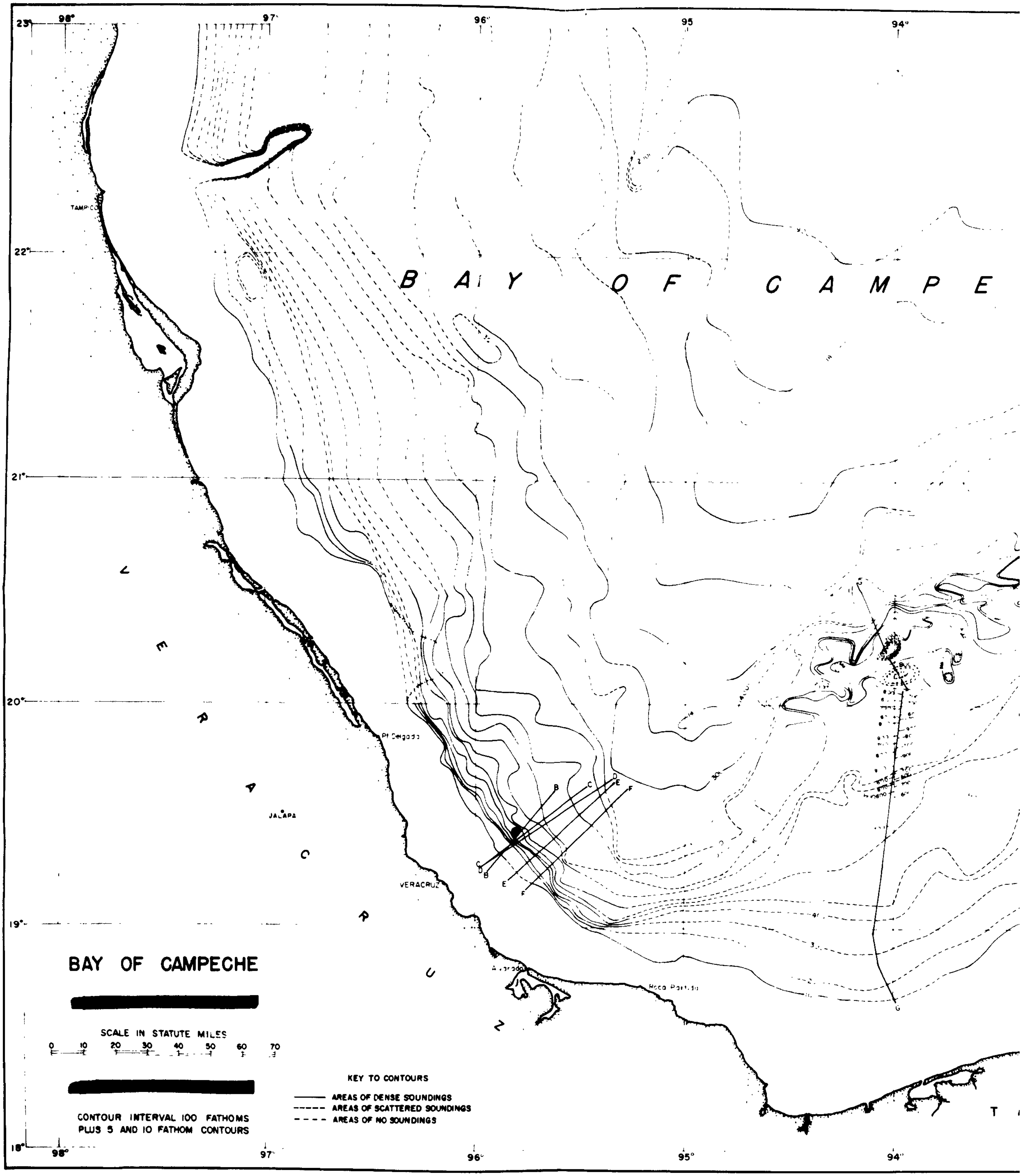

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